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Point Guard – Computer Vision-Based Interactive Basketball Training Platform.

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Abstract: **-** The scope and precision of basketball skill development are sometimes restricted using subjective evaluation and manual observation in traditional training methods. The goal of this research is to develop a complete platform that combines data analytics, machine learning, and computer vision to precisely deliver feedback on players' movements, shooting mechanics, strength training regimens, and player progress. The Computer Vision-Based Interactive Basketball Training Platform - Point Guard will use the existing literature on sports technology and basketball training methods to present a game-changing solution for basketball training. Computer vision algorithms will track the body to get quantitative feedback on a player's agility, footwork, and body alignment to refine all training paradigms. Hoop Tracking allows players to practice their shooting skills while their shot mechanics and trajectory are analyzed with state-of-the-art computer vision techniques. Strength Training is a set of individual exercise programs designed based on user feedback that emphasizes muscle-building training and training for injury prevention. Progress Tracking, in conjunction with Performance Analytics, consolidates all data from other components and feeds them into a sophisticated analytical framework used to measure individual growth, consequently giving output on a personalized training recommendation. In the end, the proposed system aims to enable members to enjoy the maximum potential of playing the sport, from the novice to the professional. The proposition is to create a platform that amalgamates advanced technology with the customization of skills and analytics for valid data that will focus on improving basketball performances.

Keywords*: Basketball, Computer Vision technology, hoop tracking, movement tracking, strength training, progress-tracking*

1. Introduction

Increasing the level of sports, competition can be achieved in part through sports training. By fully utilizing the benefits of virtual technology, athletes can learn more about sports, become more adept at timing their motions, and develop their basketball skills. It can also enhance the training outcomes of various sporting events. Giving full play to the benefits of applying computer virtual technology to basketball sports training not only reconstructs the basketball training system but also significantly enhances students' comprehension of the game, realizing the comprehensive sublimation of the basketball training system. This study presents the application strategy of computer virtual technology based on the application background of the technology in basketball sports training. It combines it with the requirements of basketball sports training. Video-based motion capture systems are becoming popular within high-competition sporting activities for the nature of motion analysis. Among the above-renowned systems are the Acoustic system, Mechanical system, Sensing system, and Optical system. Acoustic systems lack accuracy and bring slow feedback to systems, while mechanical, sensing, and marked optical systems bring enhanced accuracy and high-speed capture. However, the proper equipment decreases the range of motion, and the mark point must be ideal with soft tissue. Low cost, low profile, easy to integrate, and dealer with computer vision technology are the major features of monocular cameras like Kinect. Thus, the scope of Kinect has been proven to be effective in obtaining kinematic parameters in studies. [1],[2]. Recent research conducted by the Sri Lankan Basketball Federation (SLBF) shows that basketball is rising in popularity in the country. basketball

training techniques have often used manual observation, which reduces the level of accuracy of skill development and does not provide athletes with customized coaching. Modern technologies like computer vision and data analytics are essential to overcome the drawbacks of conventional training methods [3]. This study focuses on how data analytics, artificial intelligence, and computer vision are integrated into basketball instruction in Sri Lanka. The main goal is to introduce a system that uses machine learning algorithms to examine player and ball movement data taken from smartphone camera feeds. As a result, players will receive tailored advice from the system that will focus on improving physical activity, shooting accuracy, and strategic thinking. The main objective of this study is to provide insightful information that will benefit both novice and expert players. The method is designed to help pros improve their performance and techniques and help normal players improve their skills and enjoy the game even more [4]. lastly, the application of this technology can revolutionize how basketball is coached in the nation of Sri Lanka. The cruising technology makes it possible to get involved at a greater level and be more efficient, while at the same time making it easier to individualize training. This paper will revolutionize how basketball is trained in the country and put a track on young professional and active basketball.

2. Literature Review

Playing basketball in Sri Lanka mainly comes under the Sri Lanka Basketball Federation (SLBF), which was formed in the year 1950 to promote basketball activities in the whole country. An affiliate member of FIBA Asia and previously FIBA World Zone ’06, it has remained instrumental in the growth of basketball in the sub-region as evidenced by more than 50 annual events with players’ participation standing above 10,000. Despite the enduring history, during the 1960s and 1970s neither the federation had enough trained coaches, nor wealthy elite athletes. This gap was however bridged when SLBF successfully cohosted the FIBA Middle Asia Basketball Championship in 2007 and was seen as a pointer to a determined effort to raise the standard of basketball [6]. A current literature review has revealed that computer vision and virtual technology studies have received significant consideration in the current society across various disciplines mainly in sports. For instance, during the 2005 to 2015 period, Wldchen and Mder generated 120 peer-reviewed papers, contributing to the development of computer vision for sorting plant organs based on aspects of shapes, textures, color, edges, veins, and more [5],[6]. These have been advanced in technology and when applied in sports, enable the arrival of these essentials for analysis on enhancing training. In basketball training applications, computer-generated graphics or virtual reality are revolutionary since in understanding as well as in practicing various techniques in sport, particularly Basketball, they are groundbreaking. These technologies enable an athlete to play the game, and then simulate an interaction with the game with real-life scenarios while tweaking motion in real time making the training fruitful. Not only can the implementation of virtual technology enhance learning and recognize incorrect movements, but it also reduces the danger and hazards that learners encounter when practicing [7]. Coordinating such advanced technologies in basketball coaching alters traditional training practices and provides fresh perspectives on how skill and strategic development can be achieved in this sport.

3. Methodology

The development of the computer vision-based interactive basketball training platform consists of several modules that come together to make an interactive and efficient training system. These modules rely on machine learning techniques besides advanced techniques of computer vision and real-time processing of data.

A. System Architecture

The architecture of the interactive basketball training platform consists of several interconnected modules, each responsible for specific functionalities. The primary components include:

- Data Acquisition: Captures video of the basketball player.
- Preprocessing: Cleans and normalizes the acquired data.
- Feature Extraction Module: Identifies and extracts relevant features from the data.
- Analysis and Feedback: Processes the extracted features to generate actionable feedback.
- User Interface Module: Provides an attractive interface for users to engage with the system [8].

B. Data Acquisition

The data acquisition process is fundamental to the system's operation. It captures high-quality video footage of basketball players during training sessions. The hardware setup includes:

- Cameras: Using the mobile phone camera, the application will capture the user's movements and posture. The minimum requirements for the camera Quality should be 480p or higher, the frame rate 30fps and the camera should be in a stable place preferably on the left or right side of the center line.
- User inputs: Daily the user should enter the amount of water intake, calories taken, and whether the provided exercise was completed or not need to be entered frequently.

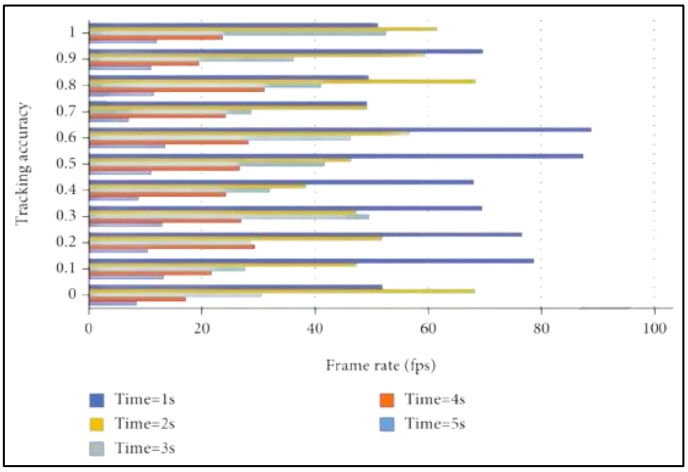

Fig 1 Tracking accuracy vs frame rate [8]

C. Data Preprocessing

Data Cleaning is an essential step in checking the accuracy and reliability of the data. The preprocessing module does the following

- Noise Reduction: Filter the video and remove noise.
- Data Normalization: To collect and normalize single data from the capturing.
- Frame Selection: Select frames from the video sequences that highlight the salient activity moments.
- User Information: Collect user-related particulars, which include the physical characteristics and training regimes. This information serves as the basis for personalizing the training plans and the responses that are given to the candidates.

D. User Interaction

- Account Creation and Login: The proposed system incorporates a Mobile application by which the users can interact with the system. The first activity requires the user to open the application or website, get an account, and log in. The above process helps in making sure that citizens' data is unique to each of them and well protected.
- Video Recording or Uploading: After signing in, the user is provided with an option to either capture a new video of the basketball session or the user can upload a video. By using a mobile

application, the interface for recording the video would be provided so that all the aspects of the training session would be captured in the video.

Server-Side Processing: Four main components form the server-side processing: Hoop Tracking, Movement Tracking, Strength Training, and Performance Analytics. Each module completes duties to analyze and produce recommendations from the video.

Hoop Tracking: From this step, the system captures frames that have the ball and the hoop. Accordingly, by utilizing state-of-the-art computer vision algorithms such as You Only Look Once, YOLO, or the Single Shot Multiblock Detector, SSD it distinguishes the ball and the hoop from these frames [9]. After a ball has been detected the system then focuses on the analysis of the ball's path. This analysis uses mathematical models and physics simulation to have a better look at the shooting performance and provides quantifiable measures behind shooting angle velocity and shooting accuracy. By encompassing them in this way, the system provides useful feedback to help improve a player's shooting [10].

Movement Tracking: The latter first extracts key moments from the video as the player coordinates movement in and through the course of the playing then the system processes the video to analyze the player's movement by using pose estimation for example, Open Pose to identify specific points on the body of the player. These detected movements are later analyzed by ML algorithms such as Convolutional Neural Networks, where certain movements like dribble, shooting, or defensive moves are distinguished [11]. Considering experimental and biomechanical data, it offers recommendations regarding these movements' optimization to adapt it to the user.

Strength Training: The strength training system, however, is very individualistic, based on the indicated user statistics, like height, weight, fat, training preferences, etc. It works in a similar way as the body, it processes data and defines what needs to be improved physically, it may recommend physical workout programs, such as lifting, push-ups, pull-ups, stretching, and the like. For the user, the system adjusts the training program as the user moves from level to level, especially using updated measurements and feedback in order not to allow the physical development of the user to stagnate. Too much focus is placed on safety with special concentration on warm-up and cool-down sessions, which enhance the general health and well-being of the clients in the long run. [12],[13].

Performance Analytics: The system retrieves the data from the database with an emphasis on such aspects as the shooting accuracy, the efficiency of the subject's movements, and their strength. This data is pre-processed to remove inconsistency and to make it more accurate [14]. It uses the database to obtain the performance data, and primary attributes, which entail shooting precision, mobility, and power. This pre-processes this data to strip out errors and make the data more precise. The data is then refined and presented normally in the form of a chart or graph so that users can have a glance at their performances and at the same time see where they are failing most. Also, the system provides meaningful recommendations that working practitioners can effectively implement.

For more user-friendly analysis, the analytics' platform enhances the trend analysis over time making the athletes understand their performance and decline in some skills and talents. Thus, the temporal data serves to increase confidence in realistic goal setting as well as modification of training schedules. In addition, the system may compare these results to average values or perfect scores to provide users with stimulus or additional context about the figures; in this way, the system can help the users direct their training and practice in the best manner to reach their greatest possible potential. [15],[16].

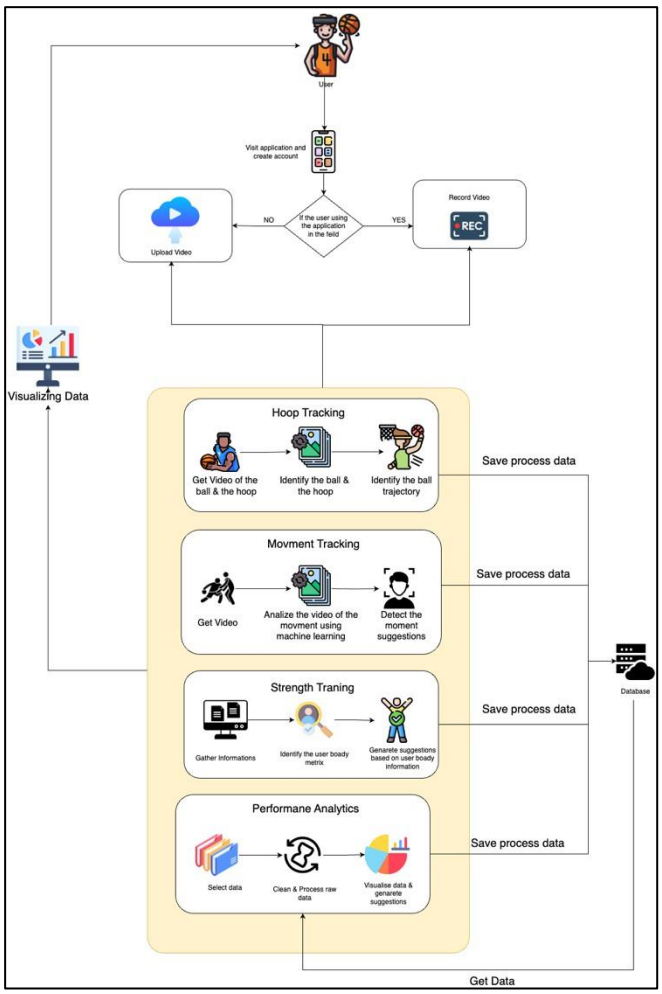

Fig 2 System overview Diagram.

E. Algorithms

For object identification, the models of machine learning are designed and trained to detect the ball and the hoop in the frames of the video. For movement analysis again, pose estimation and movement detection algorithms are used to analyze the player. These models are trained using basketball actions that have labeled data sets for the identification of movements [17]. However, trajectory analysis also entails making models and simulations to analyze the path of the ball. This is done to ensure that the models being used to predict shooting performance using the angle, velocity, and other factors are accurate [18].

Convolutional Neural Network (CNN)

CNNs are a type of deep neural networks that excel in the analysis of visual data. They contain convolutional layers that automatically pick out important details from images making them appropriate for movement tracking or hoop detection in the training platform.

K-means: The K-means clustering method splits data into K separate clusters based on feature similarity. It is useful for grouping similar types of movements or shots, enabling the platform to categorize different types of basketball plays and provide targeted feedback [19],[20].

F. Architecture

YOLOv9: The most recent version of an object identification system with great speed and accuracy is called YOLO (You Only Look Once) v8. Real-time image processing enables it to identify objects in

video streams, such as hoops, balls, and players. Its ability to perform detection quickly and accurately is crucial for providing immediate feedback during training [21].

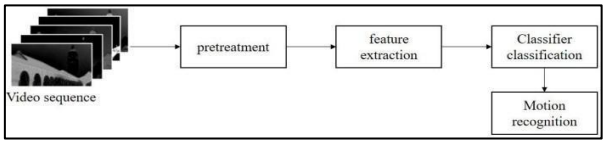

Fig 3 Motion Recognition [9].

G. Feature Extraction

Feature extraction involves identifying key elements from the preprocessed data that are indicative of the player's performance This module uses advanced computer vision techniques such as:

- Movement Analysis: Analyze the trajectory and speed of movements to evaluate performance.
- Pose Estimation: Detects and tracks the player's body movements [22].
- Object Detection: Identifies and tracks the basketball in the training environment [23],[24].

H. Analysis and Feedback

At the heart of the system lies the analysis and feedback part. It uses learning algorithms to process features and give live advice. This part includes [25].

- Check the performance: Compares player movements against a database of optimal techniques to identify areas for improvement.
- Provide future prediction: It applies models that guess future performance based on current training data.
- Generate feedback: It creates helpful advice such as visual and sound hints to help players in their training times.

4. Results

Studies conducted on the Computer Vision-Based Interactive Basketball Training Platform show that the proposed approach has a high potential for practical implementation and is efficient in applying modern technologies, namely computer vision, machine learning, and data analysis in the process of basketball training. coaching and training are centralized by the platform striving to improve the learning experience through feedback, a tailored approach, and data analysis in real-time. Here are the key findings from the research: Here are the key findings from the research [26].

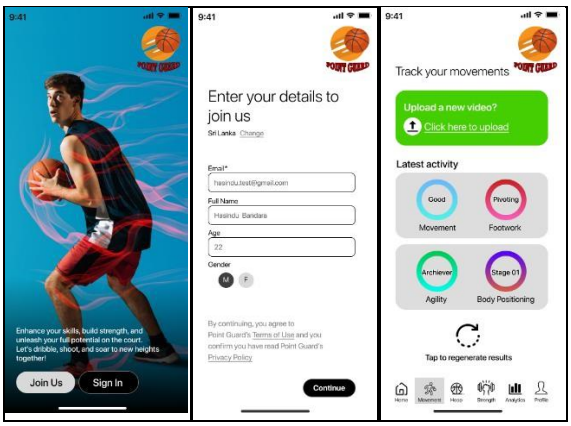

Fig 4 High-fidelity prototype.

Movement Tracking

Through computer vision, the movement tracking module successfully tracked players' movements by applying methods of background subtraction and pose estimation to identify players on the court. This in turn made it possible for coaching personnel to give aspects such as the player's footwork, quick movements, and orientation which are so vital when it comes to basketball. The successful functioning of the movement tracking was experimentally confirmed in various trials that included different players eliminating the chances of inconsistency between the results obtained from the movement tracking system and the observations of experienced coaches and trainers. Further, the research findings highlighted the realm of positive tactical and physical changes of the players during games, thus showing the practical real-life application of this technology in sports training and performance analysis [27].

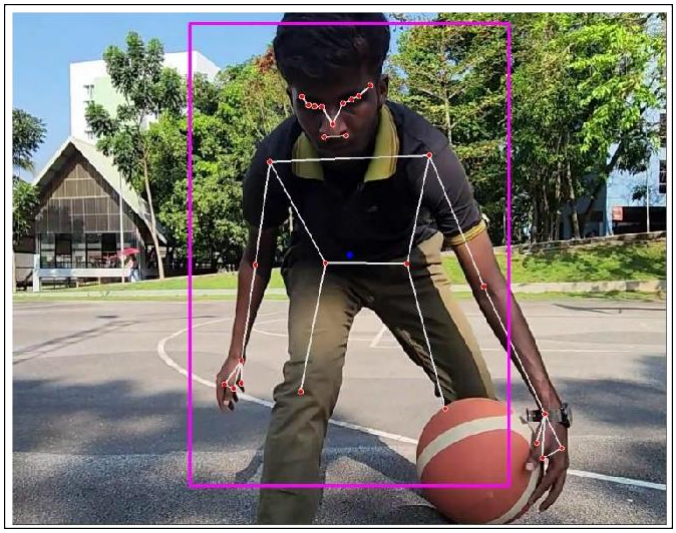

Fig 5 Hoop tracking best posture mechanics

Hoop Tracking

The hoop tracking component involved sophisticated image analysis to capture every detail of the Saint Martin's University players' movements, accuracy, and mechanical shots in basketball. When we incorporated the object detection algorithm- YOLOv8, the system performed a good job in detecting targets in real time wherein the Mobile Net

image classifier used for detecting shooting motions [28]. This setup enabled giving feedback on each player's shooting performance in the shortest time possible. Listeners were able to gain knowledge on the movements they possibly had wrong and were taught methods that may improve their shooting abilities. Finalizing the recommendation, the efficacy of the hoop tracking was already proved through regular tests in which the data provided by the system was compared with the actual shot outcomes. In the aspect of shooting the research findings unveiled a significant enhancement of shooting accuracy, thus preaching the efficiency of the system in enhancing the shooting talent by giving accurate feedback to the players.

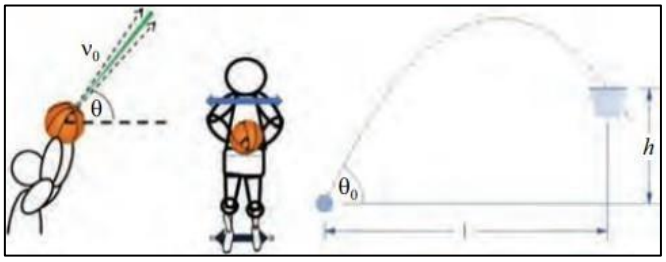

Fig 6 best posture for shooting

Strength Training

This strength training module also uses machine learning algorithms to come up with the right workout plan from age, sex, weight, and height among others. Thus, by employing the identified data picked from the workouts of players with different sensors and cameras, immediate feedback was provided to the players about the correct form and technique. The formulated strategies were important in handling some of the muscular areas that are key in the sporting activity of basketball, these include leg muscles, the stomach muscles, and the muscles of the upper arm and shoulder. Concerning the workout routines, users noted that the suggested regimes contribute to the growth of strength, better coordination, and protection against injuries.

Strength Training in the bio-training framework is established by artificial neural networks to generate new exercise regimen fields about players' characteristics including age, gender, weight height, etc. Such techniques are developed through programs that consider several player details, to ensure a high level of accuracy on the results as well as sufficient efficacy of the recommended course of treatment because of various assessment processes. As for the effects stemming from the exercise performed, they can be easily assessed in relation to various norms and standards of physiology. Integrated into this is feedback regarding exercising during the sessions using machine learning models; the models assist in the determination of the proper form in exercising and the improper form hence making the feedback received much more precise. They also use the precise strategy of teaching certain muscles for Basketball specifics with an aim of enhancing power and flexibility, enhancing the models and the amendments thereto by analyzing the enhancement via sensors and trainers' observations [29].

Performance Analytics

Their platform incorporated analytical tools to monitor progress at the closer working level. With the data gathered from movement tracking, hoop tracking, and strength training, the system performed information about the movement and improvements in training. These reports included the practicalities of shooting precision and agility on the field and additional strength. It helped players apply new strategies as the match continued and contributed to instances of learning to enable the coaching team to fine-tune their player development programs. Quantitative findings revealed that conclusion employments of Longitudinal studies manifested significant performance gains of players as a clear indication of Data-Driven Training Programs[30]. The Performance Analytics module uses the machine learning feature to offer an insightful evaluation of the players' performance. This concerns the assessment of shooting efficiency, mobility, strength increases and other aspects of the players' improvement. Data collected from the movement and hoop tracking modules are analyzed through machine learning algorithms to recognize the patterns and enhancements in the players' abilities.

Computer Vision ML in the Computer Vision-Based Interactive Basketball Training Platform includes precision measurement, predictive middleware, and feedback loop keeper. The precision measurement models, however, do better in the evaluation of shooting and agility through its training from historical and real-time session data and being a recurrent feature regularly updated for high accuracy against the set standards. Based on these above predictive models, player performance trends can be predicted likely to improve, which is further supported by comparative studies regarding the effectiveness of the training that compares predicted results with those obtained later, proving that the training indeed works. Also, a feedback loop conveys real-time observations of the coaching process to improve these models and enhance the specificity of the player metrics' analysis, the training analytics' relevance, and accuracy.

User Experience and Feedback

In general, users reported easy usage and rated the platform valuable for their training requirements. Combining real-time feedback and feedback recommendations, personalized training schedules, and data analytics of dynamic performances offered a total training that could not be attained using conventional techniques. Several players were satisfied with the timely analysis and correction that the system offered as opposed to other systems that offered suggestions a week later. Most of the respondents, including the coaches, reported finding detailed analytics helpful in coming up with better training methodologies since concepts like performance improvement could be well assessed over time.

The proposed architecture of The Computer Vision Based Interactive Basketball Training Platform has proved quite effective and has the potential to essentially redefine the basketball training paradigm. Specifically, it maps the fundamental and advanced skills needed in the sport through computer vision and machine learning and establishes a smart data analytics environment that provides accurate and real-time feedback and training plans based on the individual's ability. According to the findings of the study, it is evident that a players' performance platform is effective in developing players' abilities and helping the players train more effectively while making it easier for coaches to have ideas on how to nurture the talent. The remaining tasks in the research will include fine-tuning the algorithms and an extension of the current dataset as well as the inclusion of more features to improve the training experience [31].

5. Conclusion

Thus, the "Computer Vision-Based Interactive Basketball Training Platform: Point Guard" comes as proof of a successful experiment with merging technology with sports. They paint staggering potential for what basketball training could look like in the future where big data and technology create an even higher bar for training strategies and athletes. Future studies and tests will enhance applications and improvements in this more advanced technology hub, opening new possibilities for achieving ingenuity standards on sports training equipment.

In the case of learning the "Computer Vision-Based Interactive Basketball Training Platform – Point Guard", the findings denote progressive improvements in the application of computing science in sports training. Moving away from the typical encyclopedic approach to basketball training, this platform presents a highly efficient and accurate method involving machine learning, computer vision, and data analytics to deliver instant feedback regarding the areas in which an individual needs improvement. The application of strict algorithms for motion tracking, hoop tracking, and strength training provided a comprehensive solution for improving the methods of training and did not restrict the improvement only to technical skills alone but also embraced physical acts that build the strength of the athlete and his mental patterning of the game.

Based on the conclusions drawn from this study, it is evident that the feature that makes the platform unique and invaluable as a tool in player training is the chance to provide instant and accurate feedback in training sessions which enhances the training efficacy and speeds up the process of overall skill acquisition among the players. Self-developed training programs are too general to solve identified needs, making the training programs developed by the platform an effective way to provide specific solutions for specific problems and, at the same improve the training outcomes and minimize incidences of injuries.

Players as well as the coaches have exhibited a positive reaction, which shows its applicability to technological use. They place the value on the fact that this option provides them with specific data on the performance of the participants in their training programs which helps them in making the right changes in their strategies. This has not only improved the training element but also promotes a higher level of satisfaction with the skills and overall progression of the players.

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